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Presentation Methods to Inform Decisions about Energy Usage

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Abstract. This paper reviews some of the body of literature on the effects of feedback and goal setting in promoting energy conserving behaviour. One of several devices that are being installed into households across the UK, the E-on Ecometer, is examined and the design of its interface critically evaluated. This is done by examining the information presented by the device in the light of the finding in the previously examined literature.

1 Introduction

Following the 2008 Climate Change Act being passed into law, the UK government has committed to reducing the UK's carbon emissions by 80% by the year 2050[1]. As the domestic market accounts for 15% of the UK's greenhouse gas emissions [2], and 30% of the UK's energy use [3], the government has created a programme with the aim of installing a smart meter and an energy monitor into every household in the United Kingdom by 2020 [4]. The hope of this project is to reduce the energy demand of the domestic market and therefore reduce the carbon emissions required in generating energy for this sector [5].

Energy is not something that is often thought about in the household; a user simply plugs a device into a wall socket or turns on the central heating and the device works. As a result, energy has effectively become invisible to householders [3].

Smart metering was chosen as the method for driving this reduction in usage, along with other measures such as housing insulation [5] as there is evidence to suggest that by making energy usage visible to the consumer, they are better equipped to make decisions about the amount of energy they use [7].

With the projected costs of the smart meter roll out being in the region of £11 billion [8], it would be reasonable to ensure that the devices being installed into every home in the UK are capable of performing the task they were designed to do.

2 Existing studies – The effectiveness of feedback

Energy monitors give the user direct feedback i.e. the user receives instant usage information direct from their meter, in addition to indirect feedback on their bills as processed by their utility company [9]. There have been several studies into the effects of direct feedback in helping users reduce their energy consumption undertaken in recent years.

Feedback is defined by the Oxford English Dictionary in Darby [9] as"…Information about the result of a process or action that can be used in modification or control of a process or system … especially by noting the difference between a desired and an actual result."

There have been several studies into the effects of feedback in driving energy conservation behaviour. The results have been largely positive. In Faruqui, Sergici & Sharif's 2010 review of the pilot programmes of energy monitors around the globe, they found that although one study showed a negligible impact on energy use reduction, energy savings could be as high as 18% with an average energy saving of 7% [10].

Although the results of these pilots are promising, many of the pilots were short term, or combined with other energy reduction measures, such as time variable tariff rates or use of prepayment meters. This clouds the studies when it comes to measuring the benefits of feedback from energy meters.

Carroll, Lyons & Denny's [11] study into the effectiveness of energy monitors in increasing energy reduction knowledge found that whilst energy monitoring does have an effect in reducing usage, the effect is much greater when combined with variable tariff rates.

McCalley and Midden [12] discuss the value of goal setting alongside feedback when encouraging energy reduction. Their experiment involved integrated feedback within an individual device as opposed to feedback from a smart monitor but the behaviour being studied is comparable. The study found that if users set their own energy saving goals, rather than having goals imposed on them, they were more likely to save energy. This experiment also took personality type into consideration, breaking the sample group into "pro-social", who are more motivated by altruism than the "pro-self" group who are more motivated by self-interest.

The experiment was not without its faults, the experiment being carried out in a laboratory setting during one day, rather than the home environment where the users were less likely to change their behaviour as a result of being observed.

The positive effect of goal setting was supported by Abrahamse, Steg, Vlek, & Rothengatter in their 2007 study into the effect of goal setting and feedback on energy usage [2]. They found that when set a 5% reduction target using a website rather than an energy monitor to give the feedback, users with feedback and goal setting had achieved a 5.1% reduction in usage, whereas the control group with no goal setting had not achieved this reduction.

Despite the positive results being shown by many of these short term studies, there has been very little research done into the long term effects of energy monitoring systems. Hargreaves, Nye and Burgess [13] have produced the best example of the very few studies looking at energy monitoring systems more than 6 months after installation. Their study involved interviews with 11 out of a group of 275 householders who had had an energy monitoring system installed for 12 months. The households had been equipped with smart meters of varying degrees of sophistication and feedback. The study found that energy monitors became "part of the furniture" after the novelty value of the meter had worn off. They also found that after an initial burst of energy saving behaviour when the monitors were installed, users settled on what they considered a "normal" level of usage and were content to try to stick to that level rather than to reduce it [13].

This idea that users may stick to "normal" levels of usage over time is echoed by Strengers' study that found that if consumption did not "…scream red" then this behaviour was seen as legitimate by users of energy monitors. [14]

2.1 Normative feedback

Possibly one of the most influential studies into using feedback to increase energy conserving behaviour was carried out by Cialdini and Schultz in 2004, looking at different ways of getting people in San Marcos, California to use lower energy fans as opposed to air conditioning (AC) to cool their homes. [15]

The experiment consisted of randomly selecting candidates and leaving different door hangers containing energy saving messages on the handles of the homes in the study. These messages included telling the householder how much money they could save, asking the householder to think about the environment, telling the householder how much energy their neighbours were saving and a control group with no messaging.

All the groups either increased their energy use in the trial period or had a very small decline that was not statistically significant, with the exception of the group who were told that their neighbours were using fans instead of AC. These households saw a drop of their average daily usage by 1.2 kWh per day.

This experiment was so successful that it inspired the creation of Opower, a company that works with utility companies to tell their users how their energy usage compares to similar homes, which in 2013 saw a 2tWh reduction in usage from households receiving information from Opower [16].

This method of promoting behavioural change has not yet been applied to energy monitors, although it is being used by energy companies, for example, E-on and First Utility, in the customer account sections of their websites [17.18].

2.2 Social feedback

André, Bühling, Endrass and Masoodian's paper [19] describes the two key types of feedback often addressed in displaying energy usage via an energy monitor; Normative and historical feedback. Historical feedback is where users can see their own usage over time in comparison to their current usage, allowing the user to better understand their consumption. [19]

This paper also goes on to identify social feedback as an area that should be looked at when addressing energy use reduction. This differs from normative feedback as it allows users to compare their usage with other individuals or groups, for example other individuals in a house or other groups within an office [19].

3 Visualisation of energy usage via energy monitors

The interface of the energy monitor is the most important part of the device, as this is where the information about usage is displayed to the user. There have been studies carried out into optimising the design of the interface. Börner, Kalz, Ternier and Specht's study into the user of visual interfaces to promote energy conservation at a university campus looked at different approaches that could be taken to encourage energy use reduction in a workplace environment. The study found that different interfaces were more effective at giving different types of feedback, with public displays to pass on information, individual displays to return personalised feedback and an element of gamification to give incentives to reduce energy usage. [20]

A more detailed study of the visualization techniques that could be used in energy monitors was carried out by Thomas Rist [21]. This study describes the objectives of visualizing energy data in the context of energy conservation and describes some of the common methods of visualizing this data. The paper discusses the benefits of displaying energy data in charts and diagrams, energy gauges and eco-visualization and ambient feedback, where for example, an image of a garden is shown, with the garden looking healthy when the user is using less than the average energy to the garden looking dead and withered when the user is using more than average [21]. The paper also looks at Interactive visual data exploration, mixed media feedback and energy related games.

4 Case study: The E-on Ecometer

The E-on Ecometer was chosen as it is the only device accessible at the time of the study. It is an older model of the installed devices containing a monochrome LCD screen which displays the feedback, a series of labelled buttons to its right and a 4 smaller buttons below. It was chosen for the case study ahead of more state of the art energy monitoring systems, such as the USEM system [22] as it is an example of what has been installed recently as part of the smart meter roll out.

The user selects which information to view by tapping the buttons to cycle through the information displayed on the screen. Using the menu button below the screen it is possible to set an alarm to sound if the household uses more energy than a specified level. On the bottom of the device are a bank of lights coloured green, orange, red and blue. The green light shows when the household is using less than 150w of power, the orange shows when the household is using between 150w and 1kw, and the red shows if the household is using more than 1kw. The blue light flashes every minute [23].

The buttons to the right of the screen have both picture symbols as well as text labels to describe their functionality. The top button is labelled “Select”. This button allows the user to cycle between displaying energy usage information for electricity or gas.

The button below is labelled “Reading/Costs”. This allows the user to cycle between seeing their usage data in kWhs or in a monetary value, in this case pounds and pence.

The next button is labelled “Usage”. This button allows the user to cycle through their historical usage for gas or electricity, depending on which has been selected using the top button. The usage displayed can be cycled through to report daily, weekly, monthly or yearly usage.

The final button on the right hand side can be used to show the household’s emission of Kg of CO_2 so the user can see the environmental impact of their usage. It is labelled “Emissions”.

Below the screen are 4 buttons that allow the user to access and navigate through the menu system. The menu allows users to change the brightness of the lights on the front of the Ecometer, and to set an alarm that will sound if the cost of daily energy usage goes above an amount that can be determined by the user.

The LCD display shows a variety of different information depending on what the user has selected to view. The display will show what energy they are using at the current time as default, along with a bar graph showing historic consumption for the last hour. On pressing a button the screen becomes backlit to allow viewing in dim light.

The choice of a bar graph is a good one for displaying quantative historical data over time in a time series [24], showing the data in a way that is easy to process and pull relationship information from [25]. The major issue with the bar graph, and all the other bar graphs shown on the device, is that they do not show a scale, which means the user can't interpret the information the graph shows except for getting very general trend information.

The user can choose to look at their usage, in kWh, pounds and pence or in Kg/CO2 over an hour as described above, over a day, a week, a 28 day period or over a year, with the usage shown in minutes, hours, days or months respectively, although this is not clearly labelled on the graph. The figure shown above all the graphs will show the usage over that entire time period. This again gives the user no specific information about their usage, such as variations that would be seen between weekend and weekday, or between different seasons with any degree of clarity other than broad trends.

The user cannot for example, see their usage for a specific day and see exactly how much greater or lesser their usage was compared to other days. This problem with the unlabelled graphs is particularly apparent in the case of high usage households as the graphs appear to have an upper limit; different usage over an undisclosed threshold will appear to be the same (Figure 1). This poor information design means feedback about long term energy usage in high usage households is not available. The lack of clear visibility of past usage also makes it difficult to use the alarm feature as the user cannot easily work out what they are using on average. This makes setting energy saving goals arbitrary, which in turn will make them difficult to stick to so ultimately the user will not sustain motivation to reduce their usage [12]. This is particularly disappointing as it would be logical to assume that high usage households would be the primary target to reduce CO2 emissions.

Much information is available to the user through the E-on Ecometer, but because of the choices made in design of the interface, the feedback the device returns is of far less value than it could have been. This will make goal-setting extremely difficult thereby reducing influence on user's behaviour to use less energy.

There is also no normative feedback which has been shown to be very effective in stimulating energy reduction behaviour, allowing the user to see a socially derived baseline to compare their own usage to [15].

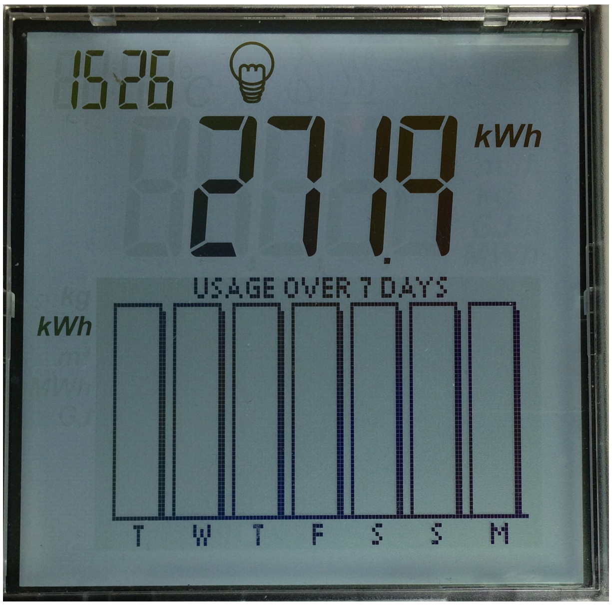

Figure 1. Yearly electricity usage display for a high usage household. (Author, 2014)

5 Conclusions

It is not obvious how the design of the E-on Ecometer interface aligns with the behavior changing objective motivating its introduction. The axis of displayed graphs is not labelled. The aggregated numbers it displays give a limited subset of potentially available usage information, reducing its value as feedback and therefore it's utility for self-setting usage reduction targets. This lack of valuable clear information may add to the backgrounding effect the device will suffer from, further reducing its effectiveness.

Considering the huge sum of money being spend on the smart meter rollout through either direct government funding or additional cost on the user's energy bill, it is surprising so few user studies have been carried out [19] to determine how effective the current interfaces are and what can be done to improve them.

The smart meter rollout is happening now, with energy monitors being installed into households throughout the United Kingdom every day. Validating guidelines for incorporating what is known about influencing behavior change into the design of such devices is urgently needed. This will require studies that monitor effectiveness over a period longer than a few months. This work needs to be undertaken as soon as possible as the rate of installations is set to increase and without validation of the designs of the monitor interfaces, the project could easily turn into a very expensive waste of effort.

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